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Article

Self-selected gait modifications to reduce the internal knee abduction moment in Alkaptonuria patients

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Introduction: Alkaptonuria (AKU) is an ultra-rare inherited autosomal recessive metabolic disorder [1]. A defected copy of the HGD gene results in a melanin-like polymer being produced which binds to all fibrous connective tissues and cartilage leading to joint ochronosis [1]. There appears to be a rapid increase of symptoms ~30 years including ochronosis levels, joint pain [1, 2] and a decline in gait [3]. It is evidenced in Osteoarthritis that joint loading of the knees, particularly the frontal plane contributes to the degeneration of the articular cartilage [4]. Sharing similar pathologies, it is expected that increased joint loading would further accelerate joint disease progression in AKU.

Research Question: How do AKU patients naturally modify their gait with age to reduce the internal knee abduction moment (IKAM)?

Methods: A 3D gait analysis (Vicon Oxford, UK) was conducted on 36 AKU patients (16 – 70 years, 14♀/22♂) who walked at a self-selected speed across a 10m walkway. Patients had reflective markers placed on the lower limbs in accordance with the Helen-Hayes model [4] to allow joint angles, moments and powers to be calculated. A healthy control group of 17 (20-60 years, 10♀/ 7♂) were used, data was collected at a variety of speeds (very slow, slow, normal and fast (0.6-2m/s)) to allow speed-matched comparisons. A 1D independent t-test was performed on the gait data using statistical parametric mapping to compare differences between the three age groups (Young:16-29y, Middle:30-49y and Old:50+y) of AKU patients and their respective speed matched control group (Young to normal (1.30m/s), Middle/Old to slow (0.96m/s)). All SPM analyses were conducted using the open-source SPM1D package (v.M0.4, www.spm1d.org) in Matlab (R2017a, Mathworks Inc., Natick, MA, USA) corrected for nine comparisons (alpha=0.0055).

Results:

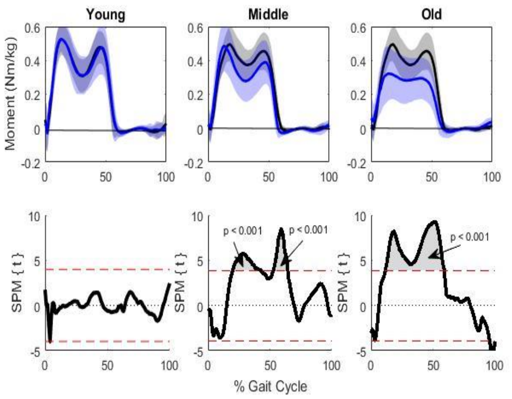

Figure 1: Internal Knee Abduction Moment mean±SD for three age groups (AKU = blue, Control = black). Where the SPM{t} curve crosses the critical threshold (dotted red lines) there was a significant difference between the curves.

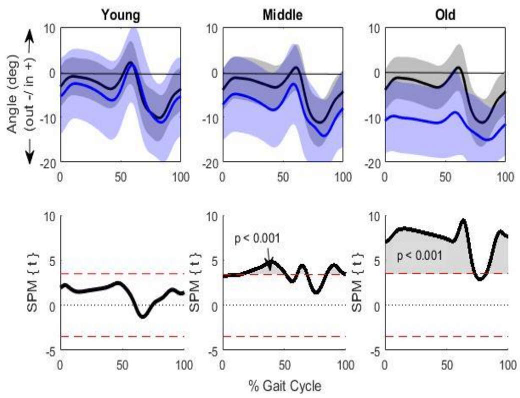

Figure 2: Foot progression angle mean±SD for three age groups (AKU = blue, Control = black). Where the SPM{t} curve crosses the critical threshold (dotted red lines) there was a significant difference between the curves.

The SPM results from the IKAM (figure 1) show a significant decrease with age. The SPM results from the foot progression angle show out-toeing significantly increases with age (figure 2). Hip external rotation is also significantly increased throughout stance in the old group compared to the healthy speed matched control ($p<0.001$).

Discussion: This study identifies for the first time an age-adaptation mechanism whereby AKU patients naturally modify their gait to reduce the IKAM which is considered as an indirect measure of joint loading [4] and ultimately linked to their joint pain. This is done by out-toeing which mechanically moves the force vector closer to the knee joint centre in the frontal plane reducing the lever arm length, resulting in a reduction of the IKAM. The external hip rotation allows for greater out-toeing seen in the old group. Previous studies focus on the global deviations from normality suggesting that gait deviations are a negative outcome however some deviations could be compensations that are beneficial to reducing joint loading and pain. **References:** [1] Introne & Ghal, (2003). [2] Ranganath & Cox, JIMD (2011) 34:1141-1151. [3] Barton et al., JIMD Rep (2015) 24:39-44. [4] Andriacchi et al., Ann Biomed Eng (2004) 32:447-457. [5] Hunt et al., J Biomech (2006) 39:2213-2220.